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Description

# Method and radio station for signal transmission in a radio communications system

The invention relates to a method and a radio station for signal transmission in a radio communications system, in particular in a mobile radio system.

In radio communications systems, information such as voice, video information or other data is or are transmitted by means of electromagnetic waves via a radio interface between a transmitting and a receiving radio station, for example a base station and a mobile station, respectively, in the case of a mobile radio system. The electromagnetic waves are in this case transmitted at carrier frequencies which are in the frequency band intended for the respective system. The carrier frequencies for the GSM mobile radio system (Global System for Mobile Communication) are in the 900 MHz, 1 800 MHz and 1 900 MHz bands. Carrier frequencies in the band around 2 000 MHz are intended to be used for future mobile radio systems using CDMA and TD/CDMA transmission methods via the radio interface, such as the UMTS (Universal Mobile Telecommunication System) or other 3rd generation systems.

The signals to be transmitted are produced in a transmitting devices in the radio station. The transmission signals are supplied via cable links and various other devices such as preamplifiers etc. to an antenna device which, in the end, transmits the radio signals. The transmitted radio signals are received and evaluated by a receiving devices in the received radio station.

In real operational conditions for radio communications systems, the radio signals are subject to widely differing types of interference and reach the receiving device on very different propagation paths.

Apart from a direct propagation path, the radio signals can also be reflected or refracted on obstructions such as mountains, trees, buildings and the like. The radio signals from the various propagation paths are superimposed in the receiving device. This leads to cancellation effects which at times have a severe adverse effect on reception of the radio signals, in this context refer to J.D. Parsons, "The Mobile Radio Propagation Channel", Pentech Press Publishers, London, 1992, pages 108-113.

Various methods are known for overcoming these cancellation effects, which are also referred to as fading effects. These fading effects can be reduced by antenna diversity, that is to say by using a number of antennas for the transmitting and/or receiving device. However, since the use of antenna diversity means an increase in the costs and complexity in the base station and in the mobile station of a mobile radio system, antenna diversity has so far been used only in the base stations.

Furthermore, it is known from the GSM mobile radio system for the reception conditions to be improved by using a frequency hopping method (FH), that is to say changing the transmission frequency for the radio signals (M. Mouly, M.B. Pautet, "The GSM System for Mobile Communications", 1992, inter alia, pages 218-223). Furthermore, methods and devices are known from the prior art according to the documents DE 44 32 928, WO 93/20625 and WO 95/32558 which use a combination of a frequency hopping method and an antenna diversity method. Apart from complex implementation, these methods have the disadvantage that they cannot be used for the broadband 3rd generation mobile radio systems, for which it is predicted that only one frequency band will in each case be available for the uplink and downlink direction for the FDD method (FDD - Frequency Division Duplex), and one frequency band for the uplink and downlink

direction for the TDD method (TDD - Time Division Duplex).

A mobile radio system based on microcells is known from the article by Kondo, Suwa "Linear Predictive Transmission Diversity for TDMA/TDD Personal Communication Systems", IEICE Trans. Commun., Vol. E79-B, No. 10, October 1996, pages 1586-1591, in which the base station makes a linear prediction of the signal strength at the mobile station on the basis of the reciprocity between the uplink and the downlink direction. The base station receives a signal in the uplink direction from the mobile station using reception diversity by means of two antenna devices, and measures the signal strength of the received signal during the reception time. The base station uses these measurements to determine which antenna produces the greatest signal strength at the mobile station location, and the base station then transmits the signal in the downlink direction via the predicted antenna.

The invention is based on the object of specifying a method and a radio station which allow the cancellation effect in future radio communications systems to be reduced. This object is achieved by the method as claimed in the features of the independent patent claim 1, and by the radio station as claimed in the features of the independent patent claim 17. Developments of the invention can be found in the dependent claims.

According to the invention, in the method for signal transmission via a radio interface in a radio communications system as claimed in the independent patent claim 1, which uses a subscriber separation method to distinguish between signals, in which a radio channel is defined at least by a frequency band and a connection-specific fine structure, at least one radio channel is assigned for signal transmission between a first and a second radio station, and at least one signal is transmitted via at least two transmission

paths. At least one characteristic value relating to the transmission conditions on the radio interface is determined for each transmission path. A control signal is derived from a comparison of the mutually corresponding characteristic values, by means of which control signal the transmission path is selected specifically for the radio channel for transmitting a subsequent signal.

This method advantageously offers the capability to determine a characteristic value for each transmission path, in order to carry out an assessment of the transmission conditions for this transmission path. The comparison of the respective characteristic values determined for each transmission path is used to select the most suitable path, and one or more subsequent signals are transmitted on this path. The determination of the characteristic values is carried out separately and specifically for each radio channel, since the transmission conditions may differ depending on the respectively used connection-specific fine structure. In consequence, the special feature of this system, which is that a number of radio channels within one frequency band are used for signal transmission, is taken into account since the optimum transmission path is determined for each radio channel, as a result of which the transmission characteristics are advantageously optimized.

According to a first development of the invention, the signal is sent by the second radio station and is received via at least two antenna devices of the first radio station using diversity reception. The characteristic values are determined, and the control signal derived, from the signal received by the respective antenna device. The control signal actuates a switching device which switches a subsequent signal specifically for the radio channel to one of the antenna devices of the first radio station. With this refinement, it is possible to determine in the first radio station the antenna device, that is to

say the transmission path, via which it is better to receive the signal sent by the second radio station. The result of the reception situation allows conclusions to be drawn on the transmission situation for the first radio station, and advantageously makes it possible to use the switching device to select the antenna device which offers the better transmission quality.

As an alternative to the first development, according to a second development of the invention, the signal is transmitted, separated in time, via in each case one transmission path. Based on this feature, a further refinement of the invention means that the signal which is separated in time is sent by in each case one antenna device of the first radio station, and is received by the second radio station. The characteristic values are determined from the respectively received signal, and the control signal is derived from their comparison. The control signal is used to actuate a switching device, which switches a subsequent signal specifically for the radio channel to one of the antenna devices of the first radio station. This refinement advantageously allows the transmission conditions on the radio interface to be determined in the second radio station if the latter has only one antenna device, and allows the subsequent signals to be switched to one of the antenna devices of the first radio station.

In this case, according to further alternative refinements, the characteristic values determined in the second radio station can be transmitted to the first radio station, which derives the control signal from them and actuates the switching device, or the control signal is derived in the second radio station from the specific characteristic values and this are transmitted to the first radio station, with the control signal actuating the switching device in the first radio station. As a consequence of a further development, the characteristic values and the control

signal can advantageously be transmitted using in-band signaling since, in consequence, there is no disadvantageous effect on the transmission capacity of the respective radio channel.

According to a further development of the invention, when a number of radio channels are assigned for signal transmission between the first radio station and the second radio station, the control signal is derived from a comparison of all the mutually corresponding characteristic values intended for the respective radio channels. The control signal is used to select a common transmission path for all the radio channels for the subsequent signals. This method, which is referred to as channel pooling, is known inter alia from the article by J. Mayer, J. Schlee, T. Weber "Protocol and Signalling Aspects of Joint Detection CDMA", PIMRC'97, Helsinki, 1997, pages 867-871. The channel pooling method is used advantageously, for example, in order to allow communications links to be provided with different data rates to and from radio stations, or to allow a number of services to be operated in parallel on one communications link.

As a consequence of a further refinement of the invention, the connection-specific fine structure is formed by a CDMA code. The subscriber separation methods chosen for the third generation mobile radio system UMTS, according to which a distinction is drawn between subscribers on the basis of the respective CDMA code, advantageously allows a large number of radio channels in one broadband frequency band, and thus high utilization of scarce radio resources. Based on this refinement, a further refinement uses a TD/CDMA method as the subscriber separation method. In this case, a radio channel is defined by a frequency band, a timeslot and a CDMA code. This subscriber separation method can be used particularly advantageously if the signals are transmitted using a TDD method. In this case, the signals are transmitted from the first radio station to the second radio station, and from the

second radio station to the first radio station, separated in time, in one frequency band. The refinement according to the invention allows the most suitable transmission path to be determined specifically for each radio channel in a timeslot, and to be used for transmitting subsequent signals.

In addition to the selection of a transmission path, further refinements of the invention allow at least two successive signals to be transmitted, using a TD/CDMA subscriber separation method, with the timeslot being changed and/or with the frequency band being changed, and with the respectively used timeslot or the respectively used frequency band being changed periodically and in synchronism with the time protocol of the subscriber separation method. These refinements have the advantage of increased transmission quality since, in consequence, interference which occurs in specific timeslots or in a specific frequency band interferes with only a small proportion of the transmitted signals, and thus has only a minor effect on reception, as a result of these changes.

As a result of a further advantageous development of the invention, the transmitted signals are received in the first radio station and/or in the second radio station using a joint detection method. This method, which is known inter alia from the article by J. Mayer et. al. already mentioned above, allows the reception quality to be increased advantageously since all the fine structures in use are used for detection of a signal which is coded by means of a connection-specific fine structure.

According to a further refinement of the invention, the characteristic value can be related to a reception level, a bit error rate and/or a value proportional to the signal delay time between the first radio station and the second radio station, and/or to a signal-to-noise ratio. Characteristic values which can be found particularly easily in radio communications systems are the reception level and the bit error rate

(which are quoted as scaled values RXLEV, RXQUAL) since, as a rule, they already exist in present-day implementations.

The method according to the invention and the radio station according to the invention will now be explained in more detail with reference to illustrations in the drawings, in which:

Figure 1 shows a block diagram of a radio communications system, in particular of a mobile radio system, and a radio communications system-typical operational environment which is characterized by multi-path propagation,

Figure 2 shows a schematic illustration of the frame structure of the radio interface, and of the construction of a radio block,

Figure 3 shows a block diagram of the radio station according to the invention as a base station and a mobile station in a mobile radio system,

Figure 4 shows a flowchart of the method according to the invention for the radio communications system as shown in Figure 1, and

Figure 5 shows an illustration with respect to time of an example of signal transmission from the point of view of a base station in a mobile radio system.

The radio communications system illustrated in Figure 1 and in the form of a mobile radio system comprises a large number of mobile switching centers MSC, which are networked to one another and produce access to a landline network PSTN. Furthermore, these mobile switching centers MSC are each connected to at least one device RNM for allocating radio resources. Each of these devices RNM in turn allows a connection to be set up to at least one base station BS. Such a base station BS is a radio station which can set up links via a radio interface to other radio stations, for example to mobile stations MS or to stationary

terminals. At least one radio cell is formed by each base station BS, and radio stations located in the area of this radio cell are supplied with radio resources. In addition, a number of radio cells can be supplied by each base station BS if sectorization is used or if the cell structures are hierarchical.

In real operational conditions for radio communications systems, radio signals are subject to widely differing types of interference between the base station BS and the mobile station MS, which is mentioned by way of example, and reach the receiving device in the mobile station MS on very different propagation paths. Apart from a direct propagation path, the radio signals can also be reflected or defracted on obstructions such as mountains, trees, buildings or the like. The radio signals from the various propagation paths are superimposed in the receiving device, which leads to cancellation effects which can severely adversely affect reception of the radio signals. The functionality of the illustrated structure is used by the radio communications system according to the invention.

The frame structure of the radio interface, as it is implemented in the third generation mobile radio system UMTS, is shown in Figure 2. A broadband frequency band, for example with a bandwidth of B = 5 MHz, is split in accordance with a TDMA component into a number of timeslots ts, for example 16 timeslots ts1 to ts16. Each timeslot ts within the frequency band B forms a frequency channel fk. The successive timeslots ts within the frequency band B are broken down in accordance with a frame structure. Thus, for example, 16 timeslots ts1 to ts16 are combined to form a frame fr.

When using a TDD transmission method, some of the timeslots ts1 to ts16 are used for signal transmission in the uplink direction, and some of the timeslots ts1 to ts16 are used for transmission in the downlink direction, with the transmission in the uplink

direction taking place, for example, at a time before the transmission in the downlink direction. In-between, there is a switching point SP, by means of which it is possible to vary the number of timeslots which are used for transmission in the uplink direction and the number of timeslots for the downlink direction in a flexible manner. A frequency channel fk for the uplink direction in this case corresponds to the frequency channel fk for the downlink direction. The other frequency channels fk are structured in the same way.

Within the frequency channels fk which are intended for user data transmission, information from a number of communications links is transmitted in radio blocks. These radio blocks for user data transmission are composed of sections with data d, each of which has sections embedded in it containing training sequences tseq1 to tseqn which are known at the reception end. The data d are spread on a connection-specific basis using a fine structure, a spread code c (CDMA code), so that, for example, n links can be separated by this CDMA component at the reception end.

The spreading of individual symbols of data d with Q chips means that subsections of duration tchip are transmitted within the symbol duration tsym. The Q chips in this case form the individual CDMA code c. A guard time gp is also provided within the timeslot ts, to compensate for different signal delay times on the links for successive timeslots ts.

By way of example, Figure 3 shows two radio stations, which are in the form of a base station BS and a mobile station MS in a mobile radio system. There is a radio link for signal transmission between the two radio stations BS and MS. The base station BS is equipped with two antenna devices A1 and A2 and a transmitting/receiving device TRX, via which it can transmit and receive user and signaling information. An evaluation device AW, which is also provided in the base station BS, is supplied with signals output from the respective reception path of the two antenna

devices A1 and A2, and characteristic values relating to the transmission conditions of the radio interface are in each case determined from them. Such characteristic values, which may be obtained only after internal conversions in the evaluation device AW, are, for example, the reception lever RXLEV, a scaled variable relating to the bit error rate RXQUAL, a lead time ta or a signal-to-noise ratio C/I. The characteristic values RXLEV, RXQUAL can be signaled, for example, by the mobile station MS as in the GSM mobile radio system, while the details relating to the signal delay time can be obtained in the form of the lead time ta, and the details relating to the signal-to-noise ratio C/I can be obtained from the received signals in the base station BS itself.

The characteristic values determined for the respective reception path are supplied to a control device SE which is connected downstream of the evaluation device AW and carries out a comparison of respectively mutually corresponding characteristic values. The control device SE uses this comparison to derive a control signal stsig and thus actuates a switching device UE which switches signals to be sent in radio channels downstream of the transmitting/receiving device TRX to one of the antenna devices A1 or A2. In this case, the signals can be switched independently for transmission and reception, that is to say the signals sent by the mobile station MS are, for example, received via both antenna devices A1 and A2 and are supplied to the transmitting/receiving device TRX. This is used advantageously according to the invention if the reception of the radio channels in the base station BS takes place using a joint detection method.

Various scenarios are feasible for determining the characteristic values and for deriving the control signal stsig. According to a first example, this can be done by the mobile station MS sending a signal in an assigned radio channel, with this signal being received

by the two antenna devices A1 and A2 using a diversity principle. The evaluation device AW uses this received signal to determine the respective characteristic values for the subsequent determination of which transmission path and which antenna device A1 or A2 offers the better transmission conditions. This determination process related to reception allows the transmission situation to be deduced, since the transmission conditions are generally identical for transmission and reception. The control device SE in the base station BS selects that antenna device A1 or A2 via which signals are then sent in the downlink direction in the same radio channel.

A second example indicates a further option. In this case, a signal is in each case transmitted in a radio channel to the mobile station MS, separated in time, by the base station BS. Time separation is required since the mobile station MS has only one antenna device A3 and is thus unable to receive two signals in the same radio channel at the same time. The mobile station MS is in this case equipped with an evaluation device AW in which it can determine characteristic values relating to the transmission conditions on the respective transmission path. These characteristic values which have been determined are then sent by the mobile station MS, for example via in-band signaling, to the base station BS, in which the values are supplied to the control device SE which uses them to derive the control signal stsig for actuating the switching device UE.

According to a third example, the mobile station MS may also be equipped with a control device SE, using which it derives a control signal stsig directly from the characteristic values determined in the evaluation device AW, and transmits this control signal stsig to the base station BS, with the switching device UE being actuated by this control signal stsig.

Furthermore, it is feasible for characteristic values relating to the transmission conditions for the

radio channel to be determined both in the base station BS and in the mobile station MS, and for these values to be supplied to the control device SE in the base station BS, which means that it is possible to make a more accurate estimate of the actual transmission conditions on the radio interface.

The characteristic values should be determined separately for each radio channel in a timeslot in a radio communications system having TD/CDMA subscriber separation, since the different CDMA spread codes c, as a result of which the radio channels in a timeslot ts differ, mean that different transmission conditions may also occur. In the situation where a number of radio channels are assigned in one timeslot ts for signal transmission between the base station BS and the mobile station MS, for example using the channel pooling principle as has already been explained in the introduction to the description, characteristic values are determined separately for each radio channel and signals which in each case have to be sent from the base station BS are sent via the antenna device A1 or A2 which has the better transmission conditions. During the process of assigning radio channels in a timeslot ts to a number of mobile stations MS, this refinement means that the best transmission path is selected for each radio channel. Depending on the selected antenna device A1, A2 via which subsequent signals will be sent in the respective radio channel, the transmission power for each timeslot ts and CDMA code c can be controlled separately, as it were.

The method according to the invention can also be applied, for example, in the same way to CDMA subscriber separation methods, in which a radio channel is in each case defined by the frequency band B and a CDMA code c. In this case, characteristic values are in each case determined and a transmission path for the radio channel is selected, for example, at periodic time intervals.

The method according to the invention can be simplified in that, for example, a number of radio channels which have been assigned to a single communications link between the base station BS and a mobile station MS on the channel pooling principle are each sent via only one antenna device A1 or A2 of the base station BS if the differences in the transmission conditions on the basis of the different CDMA code c are not significant. This likewise simplifies the process of controlling the transmission power for transmission to the individual mobile stations MS.

If it is found during the process of determining the characteristic values for the reception paths that the difference between the respectively determined characteristic values for the two reception paths of the antenna device A1, A2 is not greater than a predetermined threshold value, that is to say the transmission conditions for both paths are, for example, virtually identical, protected signal transmission can be achieved by periodically changing between the antenna device A1, A2 when the base station BS is transmitting. This results in successive, decorrelated signals at the mobile station MS location, thus advantageously improving the transmission quality when interference is present on the radio interface.

For additional decorrelation of successive signals, it is also possible, for example, to change the timeslot ts while maintaining the assigned CDMA code c if transmission problems occur repeatedly in specific timeslots ts. A further option, in the situation where a number of frequency bands B are available to the radio communications system, is to change between the frequency bands B using a type of frequency hopping method.

Figure 4 shows an example of a flowchart for one refinement of the method according to the invention. By way of example, in the flowchart block identified by the number 1, a signal is sent via the radio interface between from the mobile station MS to

the base station BS. The transmitted signal is transmitted, for example, in an assigned radio channel. The block identified by 2 represents reception of the transmitted signal in the base station BS via two antenna devices A1 and A2 using diversity reception. According to the blocks 3 and 4, the signal received via the respective antenna device A1 and A2 is used to determine characteristic values relating to the transmission conditions on the radio interface for the respective transmission paths. The characteristic values which are determined and correspond to one another are compared with one another in the block 5, and this can be done, for example, in an evaluation device AW in the base station BS. The decision resulting in the selection of the better transmission conditions is made in the decision block 6 depending on the type of characteristic values. If the transmission conditions for the transmission path via the first antenna device A1 are better than the transmission conditions via the second antenna device A2, then, in the block 7, the signals to be sent subsequently are switched in the radio channel via the first antenna device A1 to the mobile station MS. If, on the other hand, the transmission conditions via the second antenna device A2 are better, then, as shown in block 8, signals to be sent subsequently by the base station BS are sent via the second antenna device A2.

In addition to the procedure shown in Figure 4, the sequence can be supplemented, for example, by checking the difference between the specific characteristic values of the reception paths. Provided this difference is not greater than a predetermined threshold value, then signals to be sent subsequently are alternately switched to in each case one antenna device A1 or A2 using an antenna hopping method, thus advantageously decorrelating the transmitted signals. The evaluation of the signals sent by the mobile station MS can in this case be controlled by a timer,

which is matched to the subscriber separation method and/or is synchronized with it.

Figure 5 shows a three-dimensional diagram in which, by way of example, signal transmission according to the invention is carried out in a radio communications system having TD/CDMA subscriber separation and in which the uplink and downlink directions are separated using a TDD method. Firstly, the time t is plotted in the horizontal plane and is split into frames fr1 to fr4 using the TDMA subscriber separation method. Each frame fr1 to fr4 is subdivided into, for example, 16 timeslots ts1 to ts16. As has already been explained with reference to Figure 2, the uplink and downlink directions are separated by a switching point SP, so that transmission takes place in both the uplink direction and the downlink direction within one frame fr. Furthermore, a distinction on the basis of the CDMA code c is made in the horizontal plane. By way of example, four possible CDMA codes c1 to c4 are shown, which allow separation into four radio channels within one timeslot ts when using a frequency band b. In the vertical direction, two antenna devices A1 and A2 are shown, by way of example, via which the signals can be sent from the base station BS.

The example shown in Figure 5 is based on two radio channels being assigned to a communications link between a base station BS, which has two antenna devices A1 and A2, and a mobile station MS, using the channel pooling principle. The diagram in this case shows the processes of reception and transmission from the point of view of the base station BS. This configuration, which is illustrated by way of example, corresponds to Figure 3. In the initial situation, the allocated radio channels are defined in the first frame fr1 by the timeslot ts4 for the uplink direction and by the timeslot ts12 for the downlink direction, and by the CDMA codes c1 and c3 as well. Accordingly, in the first frame fr1, the mobile station MS sends signals in the uplink direction in the timeslot ts4, using the

CDMA codes c1 and c3, to the base station BS. The transmitted signals are received via the antenna devices A1 and A2 in the base station BS, and characteristic values relating to the respective transmission conditions on the radio interface are determined for each reception path and radio channel. Depending on the result of the evaluation in the evaluation device AW in the base station BS, the signals to be sent in the downlink direction are switched to a respective one of the antenna devices A1 or A2. For example, in the timeslot ts12 intended for the downlink direction in the first frame fr1, the base station BS sends signals via the first antenna unit A1 in the radio channel identified by the first CDMA code c1, if it has been found that the transmission characteristics for the first antenna device A1 are better (shaded areas). For example, the characteristic values can be determined in each frame fr1 to fr4. In this case, the antenna device A1 is used for transmission in each frame fr1 to fr4 for this radio channel in the example.

For the radio channel identified by the third CDMA code c3, characteristic values are determined for both reception paths, whose difference does not exceed a predetermined threshold value. In order to exploit this situation to obtain advantageous decorrelation of signals in two successive frames fr1, fr2, the signals in the radio channel are each switched alternately to the second antenna device A2 and to the first antenna device A1, as is illustrated in the diagram. In addition, the diagram shows a sequence of changing the timeslots ts between the individual frames fr1 to fr4, which can also be referred to as a timeslot hopping method. In this case, the timeslot ts respectively used for the uplink direction and downlink direction is changed in accordance with a predetermined algorithm or time sequence while retaining the CDMA code c, thus reducing the effect on the reception quality of

interference which in each case occurs only in specific timeslots ts.